Flight Surgeon Refresher Course

Section 3: Aeromedical Training

Noise and Hearing Conservation (FSRC305)

NOISE AND HEARING CONSERVATION

Introduction

Air crewmembers operate in an environment that exposes them to hazardous noise levels on a daily basis. Excessive noise poses a serious threat to aircrew safety and performance. Proper management of the effects of noise can enhance cockpit performance, promote a safe flying environment and ensure successful execution of the mission.

REMEMBER: Noise will always be present in the flying environment, but noise-induced hearing loss is a PREVENTABLE occupational hazard.

Objectives:

a. Differentiate between sound and noise

b. Describe the physical characteristics of sound and noise and how they are measured.

c. Describe the human hearing limitations

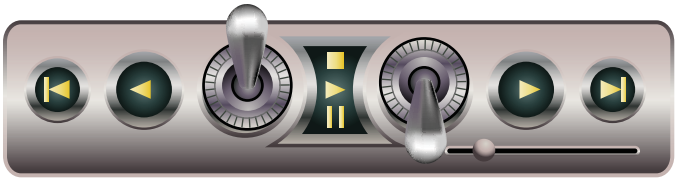
d. Describe the OSHA noise exposure limits

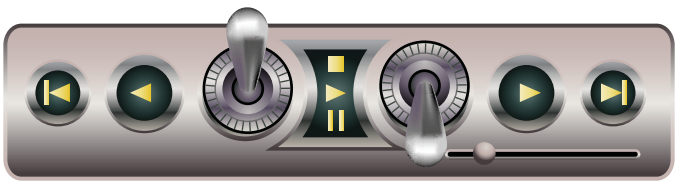
e. List the psychological and physical effects of noise.

f. List the methods used for treating adverse physiologic effects from noise.

e. List the methods used for preventing adverse physiologic effects from noise.

f. Describe the requirements for the Army Hearing Conservation Program.





What is sound?

- Sound is mechanical, radiating energy produced when an object or surface vibrates rapidly enough to generate a pressure wave or disturbance that is through a medium.
- The medium can be gas (such as air), liquid or solid.

In the aviation environment, sound is usually transmitted through the surrounding air or through the airframe itself.

What is noise?

Any sound that is loud, unpleasant or unwanted.

Noise measurement:

In the absence of calibrated noise measurement equipment it can be difficult to determine what environments are hazardous. A good rule of thumb: if, at a distance of three feet (arms length), you have to raise your voice or yell to carry on a conversation, the noise should be considered hazardous and you should wear hearing protection. Tinnitus and TTS are also signs of hazardous noise exposure.

Sound Measurements

Frequency (pitch)

- The number of times per second a sound wave oscillates.
- Frequency is the physical factor that gives sound its characteristic “pitch.”
- Measured in Hertz (Hz) or cycles per second (cps).
- The number of oscillations, or cycles per second, is then converted into the international unit of measurement known as hertz (Hz), with 1 Hz= 1 cycle per second (Cps).
- The human ear can perceive sounds from a frequency range of 20 to 20,000 Hz.
- Normal human speech ranges from 200-6,000 Hz, and as a result, this is the range to which the ear is most sensitive.

Intensity (loudness or volume)

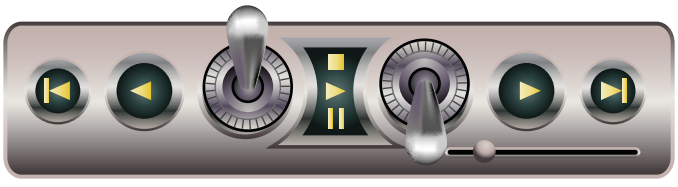
- The *perceived* loudness of a sound. Intensity correlates sound pressure with loudness.
- Measured in decibels (dB), a logarithmic scale.

Loudness (dB)	Effect
0	Threshold of hearing
65	Normal Conversation
85	Risk of damage to hearing
120	Threshold of discomfort
140	Threshold of pain
160	Eardrum rupture

Sound pressure level (in air) (dB SPL)

- Referenced to 20 µPascals
- May be scaled by A or C weighting scales (dBA or dBC), which compensate the measurement for the sensitivity of human hearing at different frequencies.
- For example, ultrasonic or infrasonic sound (outside of human hearing limits) may have high intensity levels but very low dBA levels.

If an air crewmember loses the ability to hear sound in the 300-3000 Hz range, they will be grounded because they cannot hear human speech, making communication difficult.



Hearing level (dB HL)

- Referenced to the general population hearing and refers to audiometric measurements
  - Duration (time) measured in seconds, minute, and hours
  - Dose is a combined measurement of intensity and duration that indicates when an exposure is considered hazardous. A dose of 100% or higher is considered hazardous.

OSHA/NIOSH standards

Hearing loss is directly correlated to duration of exposure and intensity: the louder the sound, the shorter the time that will cause hearing loss. Exposure to sound above 85 dB for eight hours at any frequency is the maximum permissible level.

Maximum daily allowable exposure (in Hours)	decibels
8	85
4	88
2	91
1	94
1/2	97
1/4	100

Note: for every 5 decibels of noise intensity increase, sound intensity MORE than doubles.Therefore, exposure time must be cut in half. This is important! If you cannot attenuate the noise down to 85dB or below, YOU MUST REDUCE your exposure time.

Duration...

is the time of exposure to noise. Dangerous noise can be broken down into two categories:

- **Steady state noise:** continuous sound without interruption or change in intensity for prolonged periods of time. Steady state noise is often a collection of sounds over a wide range of frequencies. Example: aircraft noise generated by engines, drive shafts, transmissions, rotors and propellers. The ear attempts to adjust to steady state noise and adapt to the intensity.
- **Impulse noise** is an explosive sound that builds rapidly to a high intensity peak and then falls off rapidly. This entire cycle is usually measured in milliseconds and it is defined as lasting less than 1 second in duration. Example: weapons firing. At close range, impulse noise can create the most damage in the shortest period of time. Even at marginal intensities, the ear is unable to safely respond and adapt to impulse noise, so temporary and permanent ear damage can occur faster than with steady state noise.
- A hearing loss at 2000 Hz and above can affect the ability to understand speech (speech may sound loud enough but can be difficult to understand, especially in noise).

Effects of Noise and Hearing Loss

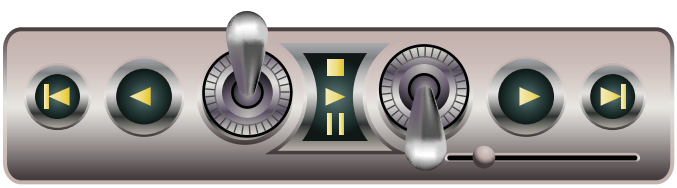
Noise can affect aircrew performance both physically and psychologically.

What are the psychological effects of noise?

- Noise interferes with concentration
- Noise interrupts speech communication
- Poor communication and concentration are leading human factors in aviation accidents

What are the physical effects of noise?

- The most common and most dangerous effect of noise is hearing loss
- The duration and intensity of noise exposure will determine whether a hearing loss will be temporary or permanent
- Hair cells become fatigued, then become damaged and eventually die from prolonged exposure to excessive noise (noise levels above 85 dB)



Aircraft Noise Levels

Fixed wing aircraft

Aircraft	Max dB	Pilot-Cruise dBA
C5-A	107	85
C-141	107	84
C-130	94	84
C-130	95	84
C-17	88	88

Rotary wing aircraft

Aircraft	dBA
UH-1H	102
AH-1	105
OH58C	103
OH-58D	104
CH-47D	112
UH-60A	108
AH-64	104
TH-67	102

Remember: Noise kills at the cellular level!

- Aircraft noise can make radio communications difficult and normal conversation almost impossible. While some people can communicate well in noise, others find it extremely difficult. Hearing loss can further hinder communication abilities in noise.
- Noise can cause stress, hypertension, and hinder performance.
- Temporary hearing loss experienced from even short duration flights or impulsive events (blasts from high caliber weapons) can hinder the threat detection, auditory communication, and spatial localization of the warfighter.

Noise Exposure Symptoms

Tinnitus (ringing in the ears)

Muffled hearing

Temporary Threshold Shift (TTS)

Permanent Threshold Shift (PTS)

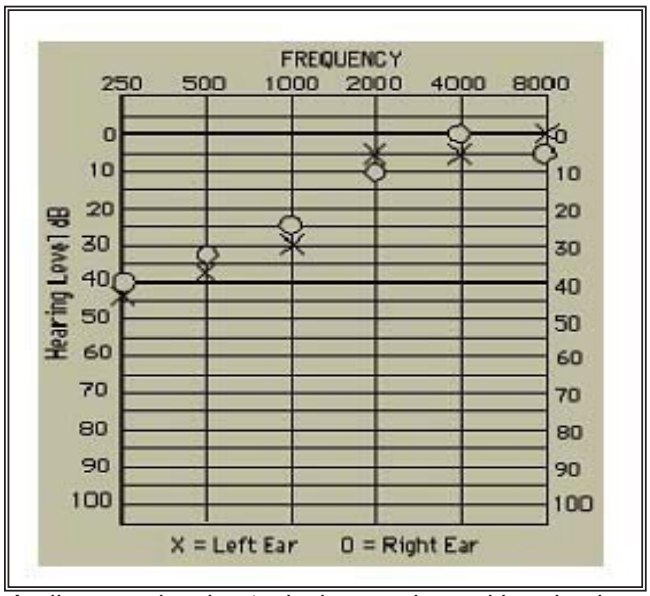
Poor speech discrimination

Poor spatial localization

Temporary threshold shift (TTS)

Temporary threshold shift is a loss of hearing sensitivity that returns to normal or pre-exposure hearing levels in time.

- Caused when hair cells in the inner ear become fatigued due to overexposure
- Can result from a single exposure to a high intensity noise exceeding damage risk criteria (85 dB)
- These threshold shifts may last from a few minutes to as long as several hours depending primarily upon the duration, intensity and frequency of the noise exposure



Audiogram showing typical sensorineural hearing loss (high frequency)

- When noise is removed, recovery is usually complete
- Common with loud music, firing ranges, or other short term exposures

What is permanent threshold shift (PTS)?

Permanent threshold shift is a loss of hearing that persists, with no recovery of sensitivity, regardless of the time.

- Caused when the hair cells are damaged or killed by excessive noise exposure
- Can be caused by impulse or steady-state noise exposure (usually after an exposure of 15+ hours).
- Recovery does not occur, even if the noise has stopped.
- Multiple short-term exposures that cause temporary threshold shifts can be cumulative, eventually becoming a permanent threshold shift if there is insufficient recovery time between exposures.

Can an air crewmember fly with a hearing aid?

Yes, if the hearing aid corrects the hearing loss and the flight surgeon gives a waiver to resume flight status.

Types of Hearing Loss

Two audiograms are included showing types of loss (sensorineural hearing loss (SNHL), conductive hearing loss (CHL) and characteristic pattern of loss. A mixed hearing loss is simply a combination of sensorineural and conductive losses.

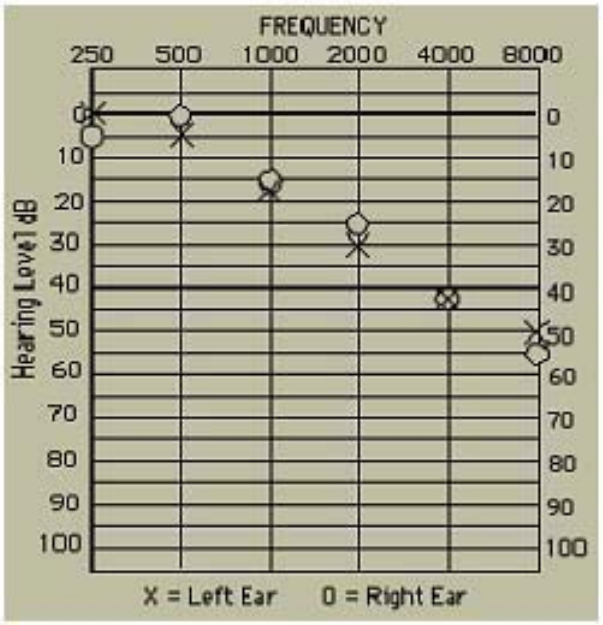
Conductive Hearing Loss

Conductive hearing loss occurs when a defect or impediment blocks the transmission of sound from the external ear to the middle ear.

- Typically affects low frequency perception
- In most cases, conductive hearing loss can be treated medically
- Hearing aids can be useful

What causes conductive hearing loss?

- Infection
- Wax buildup from disease or poor hygiene
- Fluid in the ear canal
- Calcification of the external or middle ear



Audiogram showing typical conductive hearing loss (low frequency)

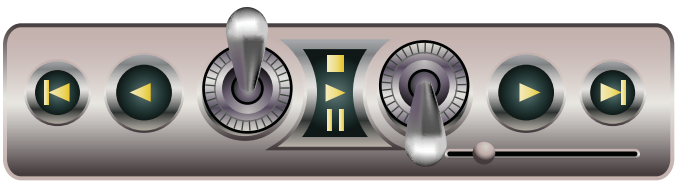
Conductive Hearing Loss Characteristics

Usually low frequency loss but can effect all frequencies equally

Usually no more than 40dB loss

Effects intensity of sound not clarity

Most frequently resulting from external ear or middle ear pathologies



Types of Hearing Loss (HL) and Common Etiologies

External Ear	Middle Ear	Inner Ear	Central Auditory
Otitis externa	Otitis media	Noise-induced HL	Tumor
Occlusion	Perforation	Ototoxic HL	Neural degeneration
Trauma	Disarticulation	Menieres' Disease	
Osteatoma Exotosis	Cholseteatoma	Presbycusis (age-related)	

Sensorineural Hearing Loss

Sensorineural hearing loss occurs when the hair cells of the inner ear are damaged.

- Typically affects high frequency perception first (3000-5000 Hz)
- This hearing loss is permanent
- Substantial loss may occur before the speech frequencies are affected
- There is no medical treatment for sensorineural hearing loss
- Hearing aids may be beneficial, but not always.

What causes sensorineural hearing loss?

- Noise exposure is the most common cause
- Heredity
- Disease
- Aging (Presbycusis)
- Large doses of antibiotics

Sensorineural Hearing Loss Characteristics

May or may not effect thresholds.

Usually effects high frequencies first but can effect all frequencies.

Noise-induced hearing loss will be seen fist at 3-6 kHz.

Can effect both intensity and clarity of sound. Usually degraded performance in noise

Speech discrimination can be poor in the presence of normal thresholds.

Mixed Hearing Loss

Mixed hearing loss is the combination of conductive and sensorineural hearing loss.

Example of mixed hearing loss: A crewmember with a middle ear infection (conductive) and high frequency hearing loss (sensorineural). One is treatable, the other one is not.

Acoustic trauma

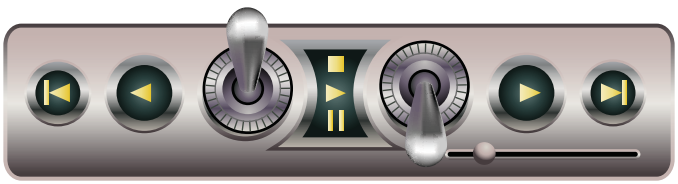
Acoustic trauma is a hearing injury caused by impulse noise causing hearing loss.

- It can be single or repetitive impulse with intensities in excess of 140 dB, usually lasting milliseconds.
- Impulse noise, such as blasts or gunfire is usually predictable; therefore, acoustic trauma is usually preventable— unless you are on the receiving end of an artillery barrage.
- Acoustic trauma injuries cause temporary or permanent threshold shifts in audible sound, with higher frequencies usually lost first.
- Temporary and permanent threshold shifts can go undetected because the hearing loss is in frequency ranges beyond the human speech range.

Treating Adverse Physiologic Effects of Noise

What are some methods of treating adverse physiologic effects of noise?

- Immediately remove soldier from noise and ototoxic chemical exposure, especially for sudden hearing loss.
- Evaluation of hearing air conduction (AC),



bone conduction (BC), speech, and acoustic immittance to determine etiology and severity

- If sudden hearing loss seems to be noise-induced, monitor hearing for TTS/PTS over next three weeks
- Re-fit soldier for hearing protectors
- Have the soldier demonstrate proper use and insertion of hearing protection
- Consult with audiologist/hearing conservation program manager to determine if hearing loss is reportable/recordable (OSHA) and if accident report form is required (DA285)
- Flight Surgeon will determine if soldier meets standards for flight IAW Flight and Hearing Conservation Standards
- Audiologists will determine Hearing Conservation Reporting requirements

NOTE: flight standards and hearing conservation program standards are not the same. A soldier may meet flight standards but still be required to complete follow-up testing for the hearing conservation program. A soldier might also require a waiver for flight standards but not show a significant change in hearing based on hearing conservation program standards. The soldier must be aware that they are to follow the standards for both programs.

Hearing aids

- All hearing aids simply increase the volume of the environment. They can also change the frequency response of the sound to help correct hearing loss in one frequency region. While hearing aids increase volume, they cannot always increase clarity. Sounds must still be processed by a damaged auditory system. Most people with hearing loss can benefit from use of hearing aids, but hearing aids do not restore normal hearing.
- Aviators with hearing aids are not grounded. However, the use of hearing aids is discouraged while in the aircraft.
- Aviators with hearing loss may see significant benefit from using a Communication Earplug (CEP). The CEP allows for noise attenuation similar to wearing both helmet and foam earplugs. The CEP also delivers an undistorted (no muffled sensation) radio communication signal to the ear. Many aviators have stated that the use of the CEP has extended their aviation careers several years.

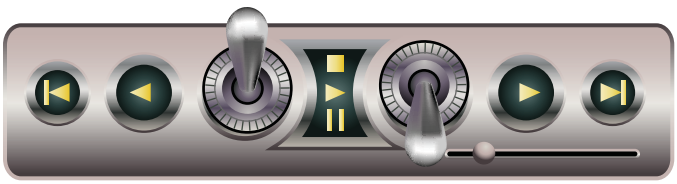
Potential Ototoxic Chemicals		
Arsenic	**Manganese**	**Trichlorethylene ***
Carbon disulfide	Mercury and derivatives	Tolulene *
Carbon Monoxide *	N-hexane	Xylene *
Cyanide	Stoddard solvent	
Lead and derivatives	Styrene *	* Highly dangerous ototoxins

Preventing Adverse Effects

Noise measurement. In the absence of calibrated noise measurement equipment it can be difficult to determine what environments are hazardous. A good rule of thumb: if, at a distance of three feet (arms length), you have to raise your voice or yell to carry on a conversation, the noise should be considered hazardous and you should wear hearing protection. Tinnitus and TTS are also signs of hazardous noise exposure.

Time limitations. Safe exposure limitations for continuous noise exposure. Limits are based on a 85 dBA 8-hour time weighted average (TWA) with a 3 dB exchange rate.

dBA	85	88	91	94	97	100	103	106
Time (hr)	8	4	2	1	-	-	-	-
(min)					30	15	7.5	3.75



Exposure Limits. Exposure must not exceed 140 dB Peak SPL for impulse or impact noise. There is no time limitation. All weapon systems (except the bayonet) exceed this limitation, including M-16 blank ammunition.

Personal Protective Equipment (PPE). Use earplugs/muffs, helmets. Soldiers who are being transported in aircraft should also wear appropriate hearing protection. Casualties/patients should receive hearing protection and instruction on proper use. Soldiers being transported in aircraft/vehicles should wear hearing protection to prevent TTS and PTS. Even a TTS from a short duration flight can have significant negative effects on the ability to hear/detect a threat and communicate with fellow soldiers.

- Enclosures can also be used to eliminate or reduce a hazard.
- Avoid ototoxic agents.
- Adhere to requirements of the Army Hearing Conservation Program (see next section):

It is important to remember that no amount of education, training, or testing will prevent noise induced hearing loss.

The only way to prevent noise induced hearing loss is by properly wearing hearing protection!

The Army Hearing Conservation Program

The Army Hearing Conservation Program is outlined in detail in DA PAM 40-501. The basic requirements are:

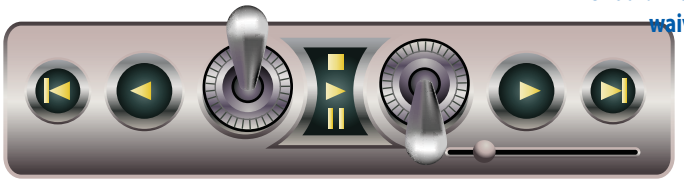
- Identify hazardous noise
- Engineer noise out of system
- Protect soldiers exposed to hazard
  - Earplugs
  - Noise muffs
  - Helmets
- Annual audiograms to monitor for change in hearing
- Annual health education
- Enforcement/command emphasis
- Program evaluation

NOTE: The aviator or soldier on flight status usually receives annual audiograms however, the flight line personnel and maintenance personnel (not on flight status) are often over looked. They have the same hearing conservation requirements (annual audio, health education, and earplug fitting) that aviators do. Do not forget to include them in your hearing conservation program. Remember you are their primary link to health care.

Hearing Conservation Requirements for Individual Aviators.

1. Annual audiogram to determine if a change in hearing threshold has occurred.
2. Soldiers who have an STS are required to complete follow-up testing within 30 days of initial test. Follow-up testing may include up to two additional tests prior to referral to an audiologist.
   a. A significant threshold shift (STS) is defined as a 15dB or greater change from baseline at any frequency (1, 2, 3, 4kHz) or an average shift of 10 dB or more at 2, 3, and 4kHz.
   b. The audiologist can:
      - profile soldier as needed
      - discuss flight waiver with flight surgeon
      - initiate accident report form DA 285
      - refer to ENT
      - issue hearing aids
      - fit and issue hearing protection
      - train soldier on proper use and care of earplugs
      - re-establish hearing conservation baseline if STS is confirmed

NOTE: The hearing conservation baseline should not be confused with the aviation waiver baseline or the OSHA baseline.



Flight Physical Requirements

- Annual audiologic test to determine if hearing thresholds meet audiometric standards
- Acceptable audiometric hearing level for Army aviation and air traffic control:

Frequencies (Hz)	500	1000	2000	3000	4000	6000
Classes 1/1A	25	25	25	35	45	45
Classes 2/2F/2S/3/4	25	25	25	35	55	65

- Do not assume that thresholds recorded on flight physical are valid. If the audiometric technician requested that the soldier return for follow-up testing, the validity of the results are in question. All follow-up testing should be complete or discussed with audiologists prior to disposition of physical. Potential problems include: TTS, crossover (requires masking), pathology requiring medical care. One aviator was found to have an acoustic tumor, indicated by STS in only one ear, but still met flight standards-aviator was referred for proper medical treatment in a timely manner (remember we meet the standard, but we treat the person).
- If standards are not met, soldier will see an audiologist for further evaluation.
- Waiver may be recommended based on results of diagnostic audiogram. An aviator will receive a special series of test to help determine if waiver is appropriate.
- Waived aviators must complete an annual audiogram (same audiogram that all aviators receive). If thresholds change by 20dB or more at 500, 1000, 2000, and 4000 Hz from the waiver baseline, another diagnostic evaluation must be completed.

Hearing Conservation Team Players (in order of importance)

These are your resources for ensuring the proper hearing health of your soldiers.

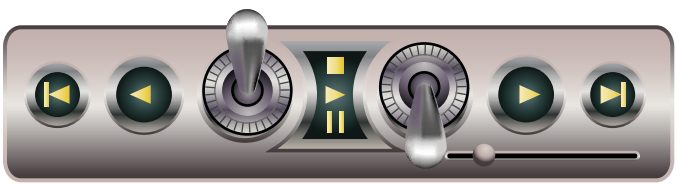
Aviators/soldier. Must protect his hearing and comply with the Army Hearing Conservation Program requirements.

Commanders. Enforce all aspects of the hearing conservation program. Will designate a unit hearing conservation manager. The commander will make or break the program. Leadership at all levels (From the Commander to the sergeant in charge of a mortar squad) must buy into the program.

Hearing Conservation Program Manager (HCPM). Acts as an advisor to commanders and unit hearing conservation managers. Usually the installation audiologist.

Audiologist. Usually the HCPM. Primary mission is hearing conservation (not hearing aids/clinic), provides diagnostic audiometric testing, earplug fitting, and health education.

Flight Surgeon/Aviation Physician Assistant (FS/APA). Primary link between soldiers and their health care. Should prevent soldiers from becoming clinical patients due to degree of hearing loss. Should encourage and advise soldiers on proper use of hearing protection.



Audiometric Technician (91W/P2). Provides audiometric testing in a TMC/medical facility. Testing is done primarily for the HCP. Data can also be used for physicals including the flight physical. Works under the HCPM/audiologist.

Safety Officer. Acts as an advisor to the commander on safety issues.

Industrial Hygiene (IH). Provide noise measurement and damage risk criteria.

Preventive Medicine (PM). Manages all preventive programs including hearing conservation.

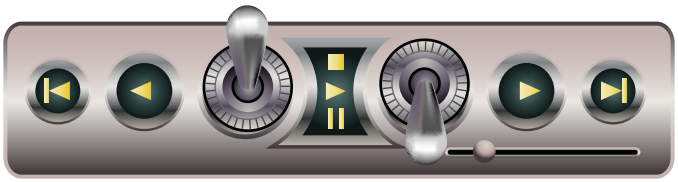
Hearing Protection

Earplugs

- Earplugs (in addition to the aviator's helmet) may be necessary to provide adequate protection in aircraft (see table)
- Triple-flange and single-flange earplugs must be fitted by medically trained personnel on an annual basis.
- Most soldiers improperly receive and attempt to wear the triple-flange orange (medium) earplug, However, there are many soldiers who should wear the large (blue) or small (green) due to the size of their ear canal.
- Earplugs are fit annually due to anatomical changes in the external canal that occur over time.
- The foam earplug is probably the most used earplug and also the most misused earplug.
    - **To be properly worn, the earplug must be inserted until most of the plug is completely surrounded by the ear canal (the tragus is not ear canal).**
    - **Most soldiers only achieve ¼ to 1/2 insertion of the earplug.**
    - **Some soldiers cannot wear the foam earplug due to the size or shape of their ear canal. Using the right hearing protection device**
- When choosing hearing protection chose the device that is appropriate for the noise hazard and operating conditions.

Aircraft	Hearing Protector	Effective Exposure Level dB
AH-1	SPH-4	83.2
	SPH-4B	77.4
	HGU-56	77
UH-1H	SPH-4	85.9
	SPH-4b	81.3
	HGU-56	81.3
OH-58D	SPH-4	86.3
	SPH-4B	81.5
	HGU-56	81.6
OH-58C	SPH-4	81.4
	SPH-4B	76.8
	HGU-56	76.9
UH-60A	SPH-4	95.1
	SPH-4B	90.6
	HGU-56	90.6
CH-47D	SPH-4	93.4
	SPH-4B	88
	HGU-56	86.8

- Using a foam earplug (high attenuation plug) might not be appropriate for an 85dB exposure as over protection will occur and communication problems may arise.
- A mechanic may not want to use a foam earplug due to the intermittence of the noise exposure and the debris/contamination that can soil the earplug when rolling and inserting into the ear.
- The ear-canal-cap may be more appropriate in these conditions.



Two chronic problems:

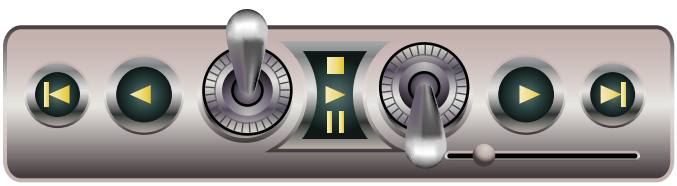
- Getting soldiers to wear ear hearing protection
- Getting soldiers to wear ear hearing protection properly

Eyeglasses

- Most aviators are good about wearing the helmet properly, but it has been shown that wearing glasses with bayonet ear pieces causes a 3dB reduction in overall attenuation.
- This reduces the safe exposure limit by half.
- Cable ear pieces or skull frames allow more hearing protection.
- If bayonet ear pieces are worn, earplugs should also be worn to provide adequate hearing protection.

The long-term cost of hearing loss

- Noise induced hearing loss is compensable for both military and civilian DoD employees. Soldiers receive compensation from the Veterans Administration (VA) that amounts to approximately $361,362,600 (2001 data) annually.
- Civilians receive compensation from the installation in which they work.
- The cost of noise-induced hearing loss is estimated at $1 billion annually.
- This includes compensation (NIHL, tinnitus), re-training of noise-exposed personnel to different MOS, and replacement of personnel and equipment lost due to accidents caused by hearing loss (i.e., poor communications).



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